NASA Innovative Advanced Concepts

Turbolift

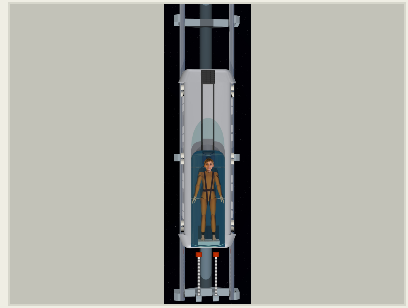
Completed Technology Project (2017 - 2018)

Project Introduction

Long duration space exploration missions cause astronauts to experience physiological deconditioning, including bone loss, muscle atrophy, cardiovascular deconditioning, sensorimotor/balance impairment, and vision changes. For a crewed Mars mission, where microgravity and reduced gravity (e.g. 0.38 G on the Martian surface) exposure may occur for 2+ years, deconditioning impacts the astronauts' health, well-being, effectiveness, and safety. Here, we propose a novel linear artificial gravity (AG) technology designed to counteract these deleterious effects on the astronauts. Previous centrifuge AG systems have negative impacts due to the constant rotating environment: 1) Coriolis forces, which may be confusing and limit concurrent exercise or lead to injury, 2) vestibular crosscoupling illusions, which are highly provocative and cause motion sickness, and 3) gravity gradients, where the loading varying along the length of the astronauts body. Alternatively, our linear AG technology (termed Turbolift) suffers from none of these confounding problems, particularly during the acceleration/deceleration loading phases. Briefly, the conceptual paradigm is as follows: the astronaut is linearly accelerated at 1G for ~1s, then is rotated 180 degrees to prepare for a 1G deceleration for ~1s. This process is repeated to create intermittent AG where the force is always headward similar to standing here on Earth. The experience is likely to be analogous to bouncing mildly on a trampoline. The intermittent loading is intended to reduce or eliminate the physiological deconditioning in a comprehensive, multi-system manner. To evaluate the linear AG technology, we aim to perform an engineering design analysis to quantify the required size and mass of the system. We also aim to design a scale model of the system to test its feasibility, such that it can be properly evaluated as countermeasure system to enable long duration crewed exploration missions.

Anticipated Benefits

This project contributes to the development of a countermeasure system to enable long duration crewed exploration missions



Turbolift to assist astronauts on long duration space exploration missions. Credits: Jace Alexander Gruber

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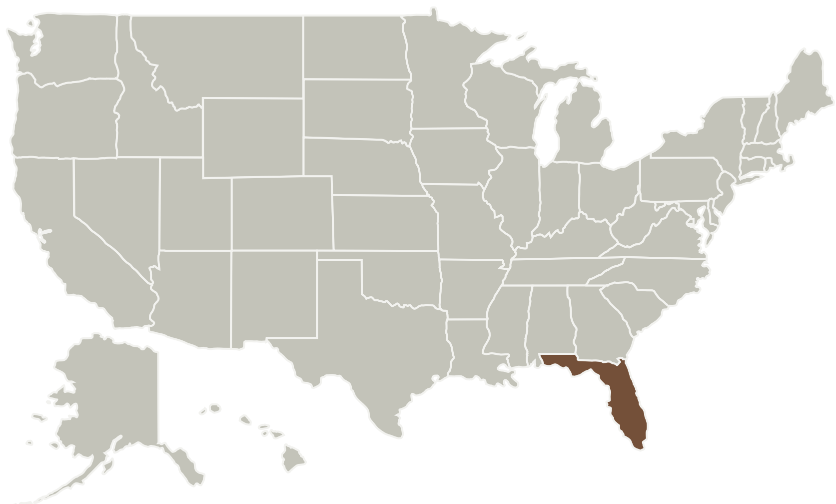
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
IMSG Laboratories, Inc.	Lead Organization	Industry	Tampa, Florida
University of Colorado Boulder	Supporting Organization	Academia	Boulder, Colorado

Primary U.S. Work Locations
Florida

Project Transitions

April 2017: Project Start

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

IMSG Laboratories, Inc.

Responsible Program:

NASA Innovative Advanced Concepts

Project Management

Program Director:

Jason E Derleth

Program Manager:

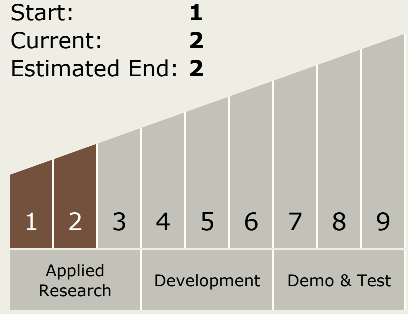
Eric A Eberly

Principal Investigator:

Jason A Gruber

Technology Maturity (TRL)

Start: **1**
Current: **2**
Estimated End: **2**



January 2018: Closed out

Closeout Summary: Future crewed space exploration missions into deep space will require enhanced countermeasure technologies to ensure astronaut health. One such hazard is extended exposure to reduced gravity levels (i.e., microgravi ty, lunar gravity, or Martian gravity). Reduced gravity negatively impacts many physiological systems, leading to hydrostatic intolerance, musculoskeletal atroph y, sensorimotor impairment, bone demineralization, cardiovascular deconditioni ng, and visual alterations1. Various countermeasures have been employed for m itigating these effects, such as exercise, pharmaceuticals, diet, and fluid loading. However, these approaches treat individual symptoms, such that each physiolog ical system is addressed with typically one countermeasure. An alternative to thi s approach is artificial gravity (AG), which promises to be a holistic, comprehens ive countermeasure2. The traditional approach to creating AG is through centrifu gation. However, centrifugation is not a pure form of AG and typically includes t he drawbacks of Coriolis forces, gravity gradients, and vestibular cross-coupled i llusions. As an alternative, we have proposed a Linear Sled Hybrid (LSH) AG sys tem to mitigate astronauts' physiological deconditioning. This system functions b y applying pure linear acceleration to produce footward loading. There is a half r otation (180°) to reorient the rider between acceleration and deceleration phase s, such that the loading remains footward, as when standing on Earth. The rotati on also provides some footward acceleration to the lower body through centripet al acceleration; hence the hybrid aspect of the design (Figure 1). At the end of t he deceleration, the rider than accelerates back in the opposite direction and the sequence repeats. This proposed system could be integrated with future crewed space vehicles in a variety of manners. One approach that we have explored is f or it to be added to the outside of the vehicle as a subsystem. We propose a pre ssurized pod to enclose the rider, which performs the sequence of motions in Fig ure 1. The system could utilize both sides of the track and have two pods, such t hat two astronauts could ride on the system at a time. The LSH AG system coul d broadly prove beneficial for any long-duration space exploration mission. As pr eviously mentioned, extended duration exposure to microgravity impairs astrona uts' ability to function and negativity impacts their health. Many of these deleteri ous effects are expected to grow with even longer duration missions than curren t 6-month International Space Station (ISS) stays. Furthermore, longer exposur es to microgravity may uncover additional physiological concerns and interaction s that have not yet been identified. For planetary landing missions to the moon or Mars, it is currently unknown whether these reduced gravity environments (0.16 and 0.38 G, respectively) will be sufficient to help mitigate or slow astrona ut deconditioning. Thus, the LSH AG system may be critical to enabling crewed l ong-duration lunar stays, cis-lunar exploration, Mars orbital missions, exploratio n of Martian moons, Martian landings, or any further destination in our solar sys tem (e.g., Europa). In the foreseeable future, we envision the LSH AG system to be directly applicable to crewed missions to Mars, which will require 1+ year of microgravity exposure, in addition to any time spent on the surface (potentially ~2 years). There are three aspects to be considered regarding the feasibility of t his system; human health benefits, human tolerability during LSH operation, an d the associated cost of engineering and designing the system. Regarding the h uman health benefits, while AG has not been validated as a countermeasure for astronauts in space, presumably replicating 1 G would be beneficial in maintaini ng human health as it is here on Earth. We consider a range of different motion sequences that might prove optimal in maintaining astronaut health during long -duration exposure to microgravity. We investigated the human tolerability of th e LSH motions via simulation of the well-validated observer computational mode

Technology Areas

Primary:

- TX06 Human Health, Life Support, and Habitation Systems
  - └ TX06.3 Human Health and Performance
    - └ TX06.3.7 System Transformative Health and Performance Concepts

Target Destinations

The Moon, Mars, Others Inside the Solar System

Images

Links

NASA.gov Feature Article
(https://www.nasa.gov/directorates/spacetech/niac/2017_Phase_I_Phase_II/Turbolift)